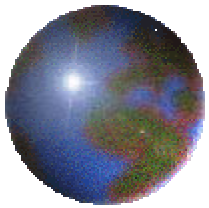
2002 DEER Conference



San Diego, California

Dave Smith - bp

August 25th - 29th, 2002

INVESTIGATION OF THE EFFECTS OF FUELS AND AFTERTREATMENT DEVICES ON THE EMISSION PROFILES OF TRUCKS AND BUSES

- **Miriam Lev-On, Chuck Le Tavec, Jim Uihlein, Ken Kimura, BP;**
- **Teresa L. Alleman, Douglas R. Lawson, Keith Vertin, NREL;**
- **Gregory J. Thompson, Mridul Guatam, Scott Wayne, WVU;**
- **Barbara Zielinska, John Sagebiel, DRI;**
- **Sougato Chatterjee, Johnson Matthey; and**
- **Kevin Hallstrom, Engelhard Corporation.**

ECD Demonstration Program

Participants

- **Agencies**
  - National
    - DOE and NREL major supporter & working group member
    - EPA review and comment on test program
  - California
    - CARB, SCAQMD and CEC are members of working group
- **Academia**
  - West Virginia University
  - University of California, Riverside
  - Desert Research Institute
- **Industry**
  - Engelhard and Johnson-Matthey with support from Corning, NGK-Lock and Fleetguard Nelson
  - Cummins, Detroit Diesel, Ford and International
- **Fleet operators**

Fuel Analysis Results

1st Round of testing
Test Fuel Properties (1 Sample)

Property	CARB	ECD	ECD-1
Cetane Number	54.1	64.7	51.3
Sulfur, ppm	121	7.4	13.1
SFC Aromatics			
Total, vol%	22.5	10.9	23.8
PNA, wt%	4.1	0.9	2.8

ECD Demonstration Program

Fleet Participants

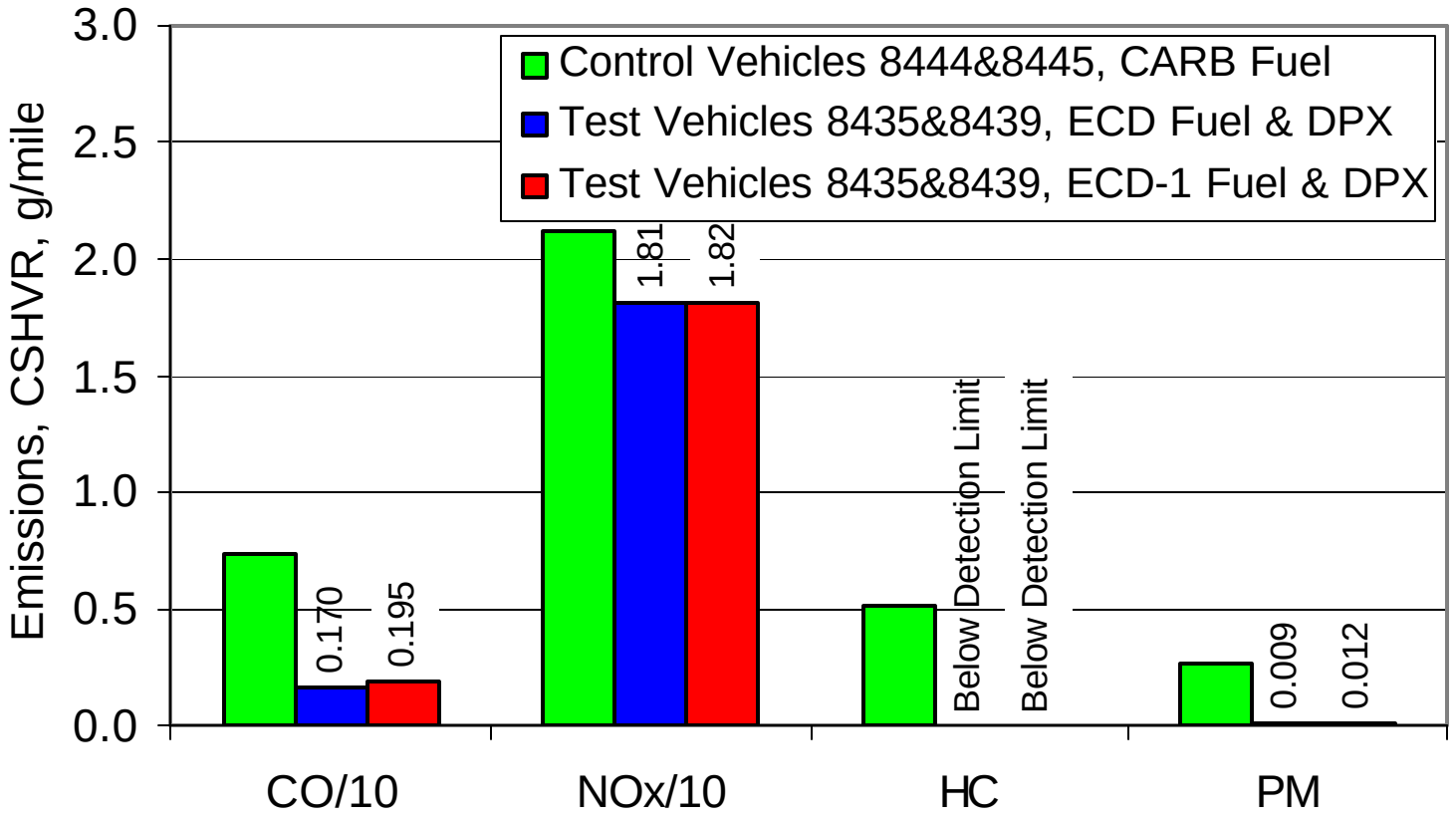
	ECD w/ Johnson Matthey	ECD w/ Engelhard	ECD with original muffler	CARB w/ original muffler	Total
ARCO	5	5	9	10	**29**
San Diego Schools	5	5	10	10	**30**
LA City	5	5	2	3	**15**
LA MTA	2		8	8	**18**
Tram vehicles	5	0	15		**20**
Hertz Equipment Rental	5	5	5	5	**20**
Ralphs Grocery	5	5	5	5	**20**
Total	**32**	**25**	**54**	**41**	**152**

San Diego School Buses

- 1998 American Transportation 3000RE International Chassis
- International 530 E 8.7 liter I6 turbo, 275hp
- Automatic transmission, 5 speed
- Engelhard DPX catalyzed soot filter
- 32,200 lb test weight

Effect of ECD and ECD-1 Fuels

School Buses with DPX Filters

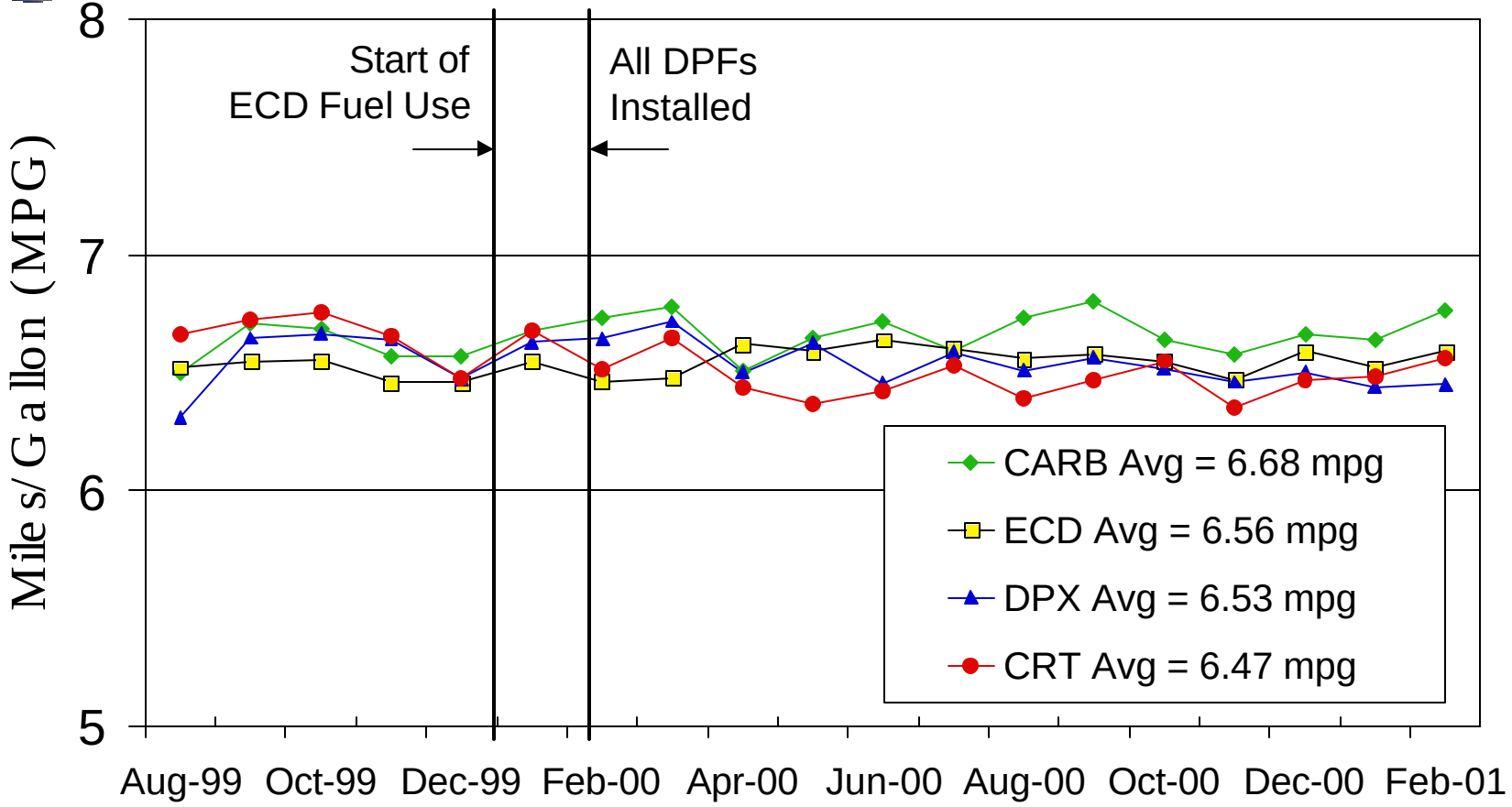


- CO, HC and PM emissions were about the same, indicating the oxidative performance of the DPX was about the same with either fuel

Ralphs Grocery Trucks

- **1999 Sterling L-line Chassis**
- **1998 Detroit Diesel series 60**
- **12.7 liter turbocharged diesel, 430hp**
- **10 spd. Manual transmission**
- **Johnson Matthey CRT and Engelhard DPX**
- **42,000 lb test weight**
- **Twenty trucks tested to investigate vehicle-to-vehicle variability**

Grocery Truck Monthly Fuel Economy

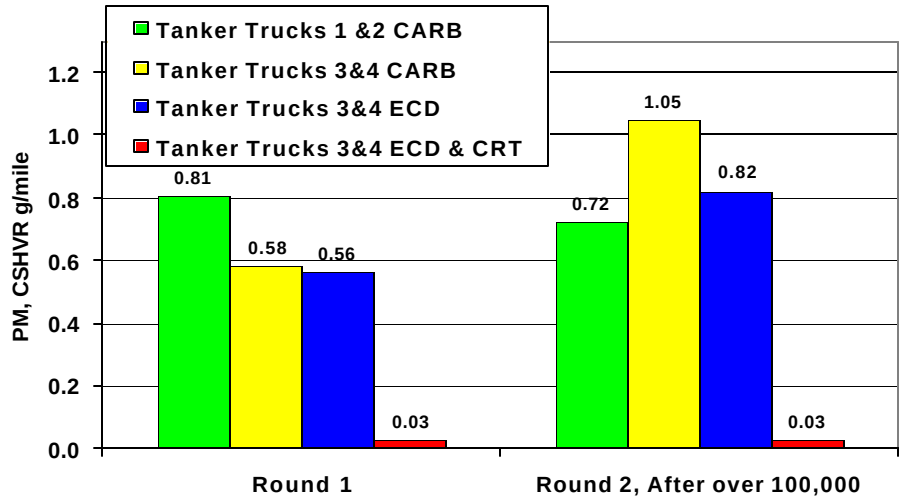


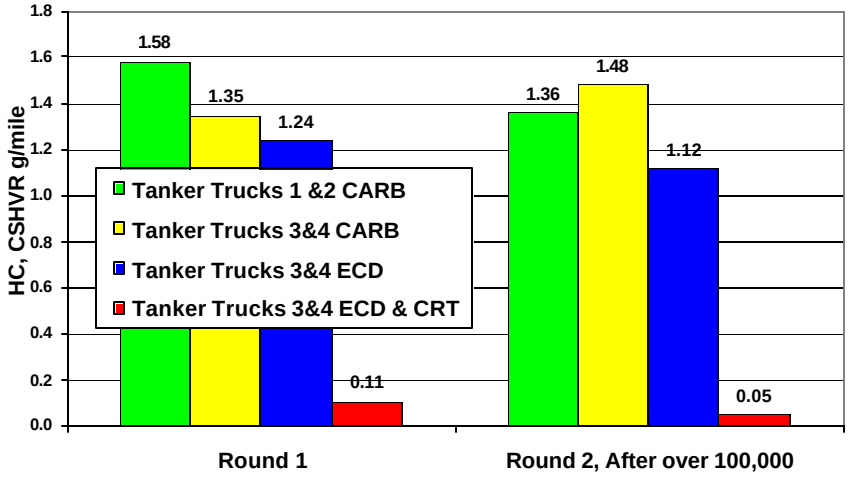
- Small average MPG differences attributed to lower energy density of ECD fuel
- Energy density difference for ECD-1 and typical California diesels is negligible

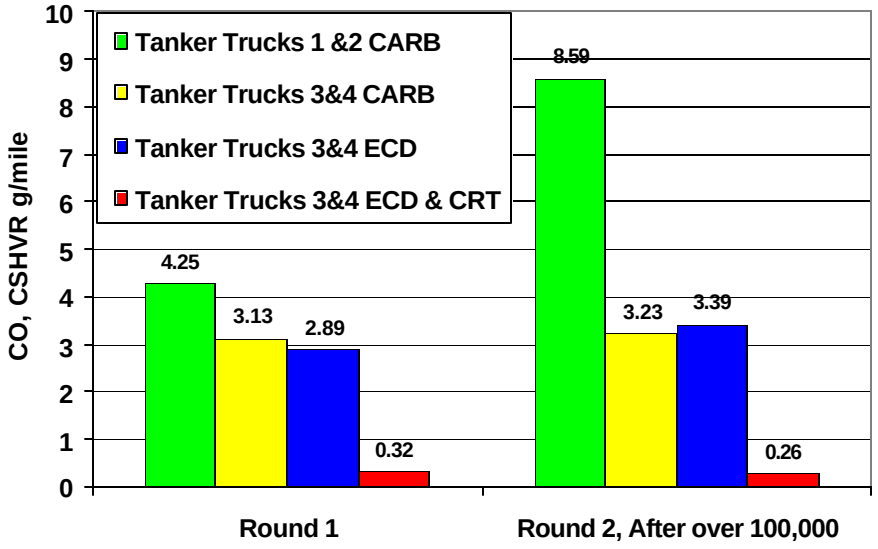
ARCO Tanker Trucks

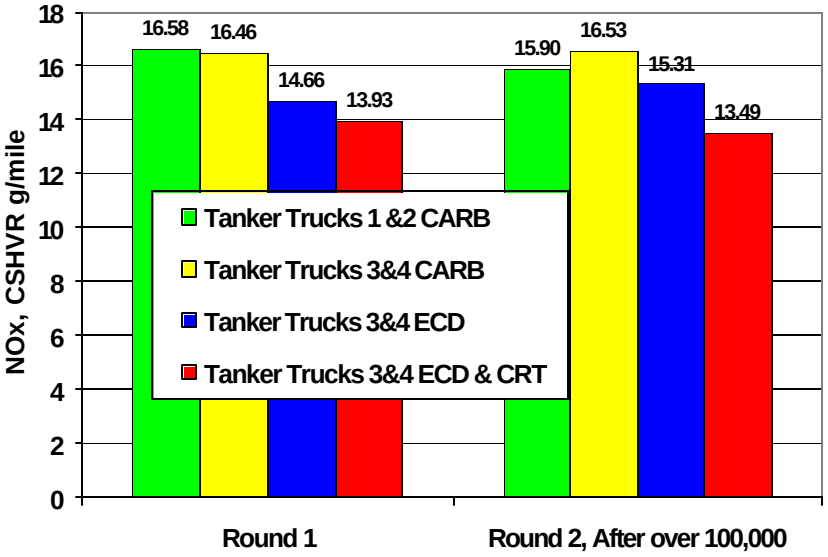
- Kenworth chassis
- 1995 & 96 Cummins M11 10.8 litre turbocharged diesel, 330hp
- 10 spd. Manual transmission
- Johnson Matthey CRT
- 32,200 lb test weight

ARCO Tanker Trucks









Speciation Data

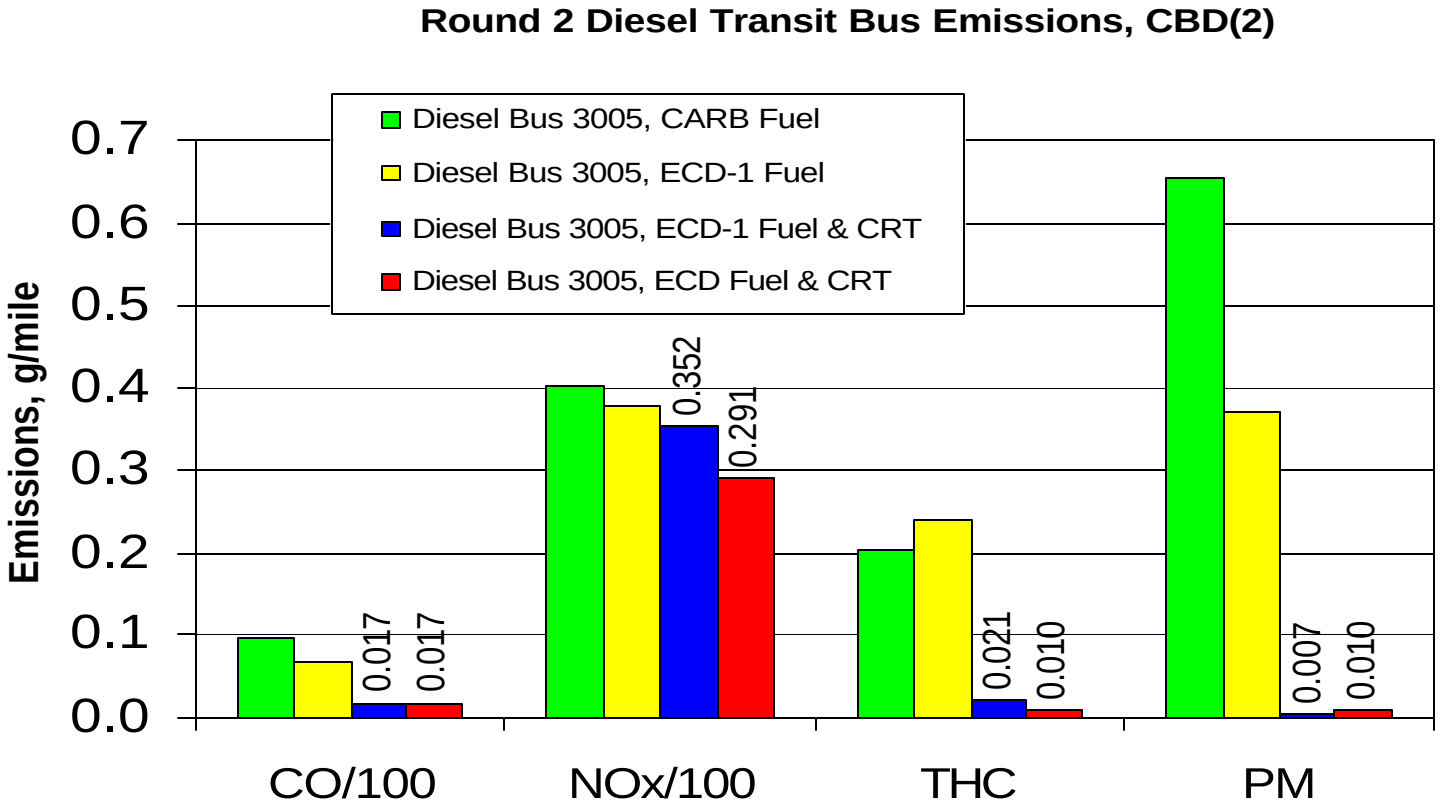
LA MTA Transit Bus Example

LA MTA Transit Buses

- **1998 Diesel New Flyer Transit Bus**
  - **Detroit Diesel Series 50**
  - **8.5 Liter, 275 hp**
  - **5 Speed Automatic Transmission**
  - **Johnson Matthey CRT**
- **2000 and a 2001 CNG New Flyer Transit Bus**
  - **Detroit Diesel Series 50 G**
  - **8.5 Liter, 275 hp**
  - **5 Speed Automatic Transmission**
  - **Close Loop Control**
  - **No aftertreatment – Compliant with Current State and Local Rules**

Effect of ECD and ECD-1 Fuels

Transit Buses with CRT Filters



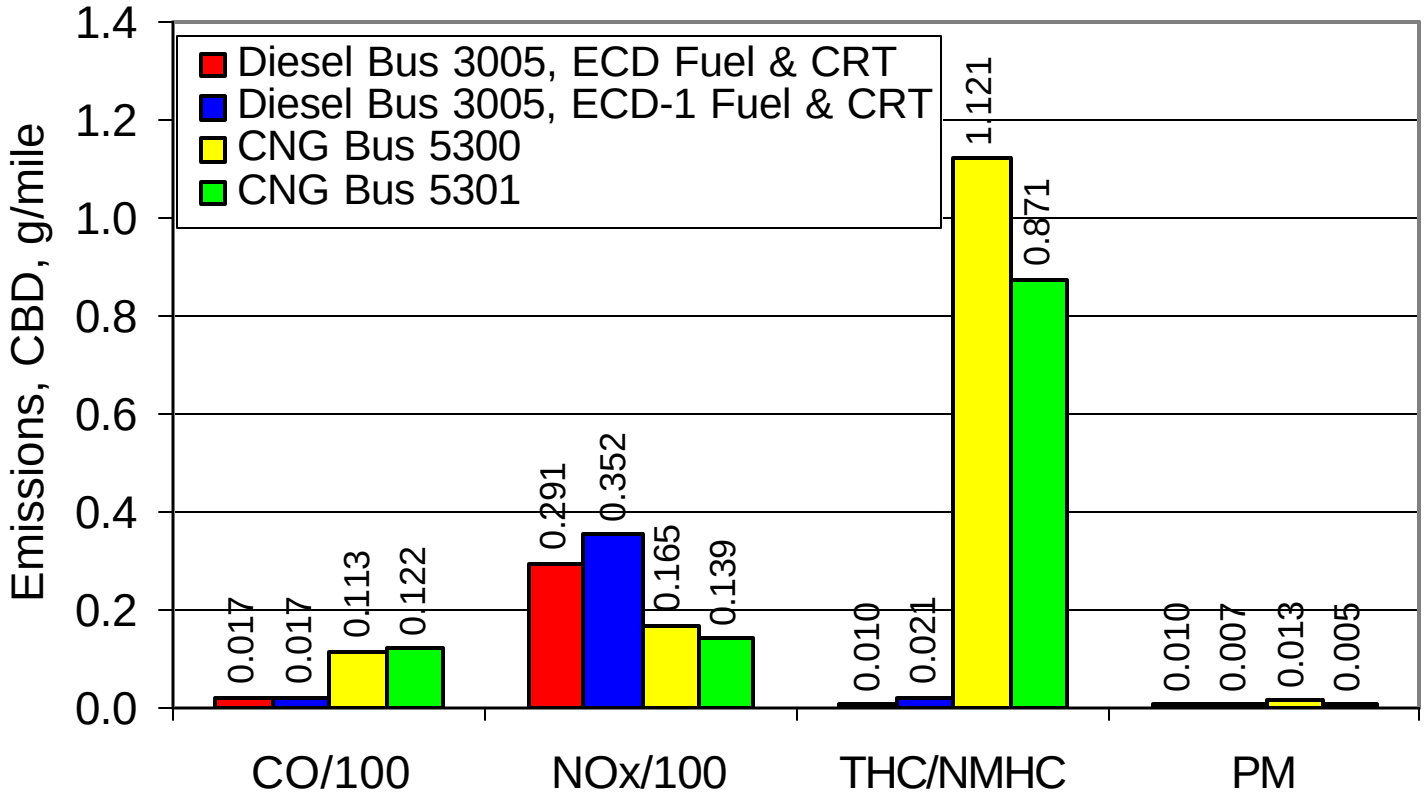
- CO, HC and PM emissions were about the same, indicating the oxidative performance of the CRT was about the same with either fuel

Speciation Testing

- Special speciation test plan was developed
  - enhanced emissions sampling
  - allow detailed analytical characterization
  - particle sizing analysis of the exhaust
- Goals to study what impact fuels and passive catalyzed particulate filters have on:
  - unregulated toxic emission species
  - particle size distribution
  - mutagenicity – still awaiting results

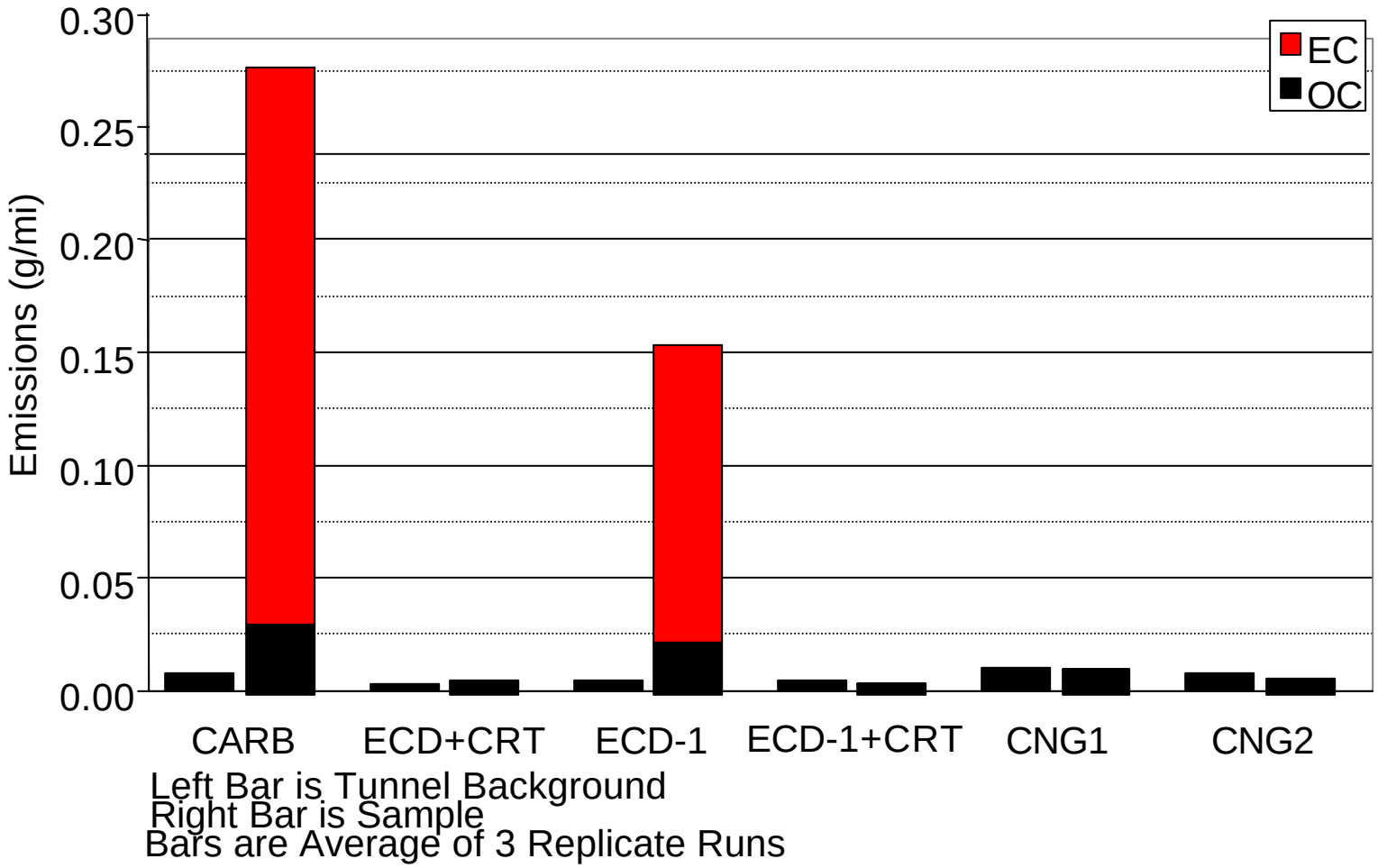
Note: Diesel engines without filters were fitted with a standard muffler with no oxidation catalyst.

Diesel vs. CNG Comparison



- Note: Total hydrocarbons presented for retrofitted diesel bus, non-methane hydrocarbons presented for CNG buses

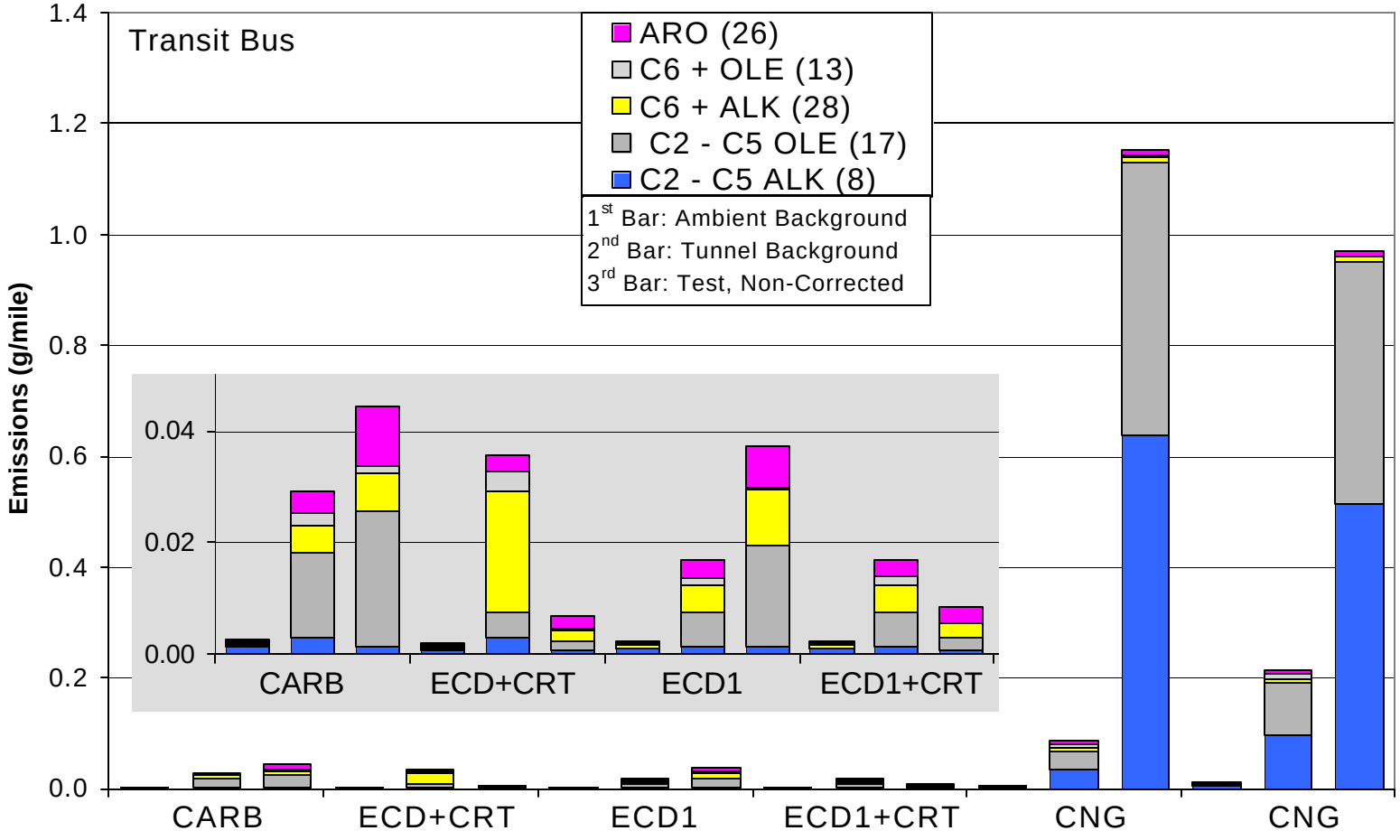
Elemental and Organic Carbon



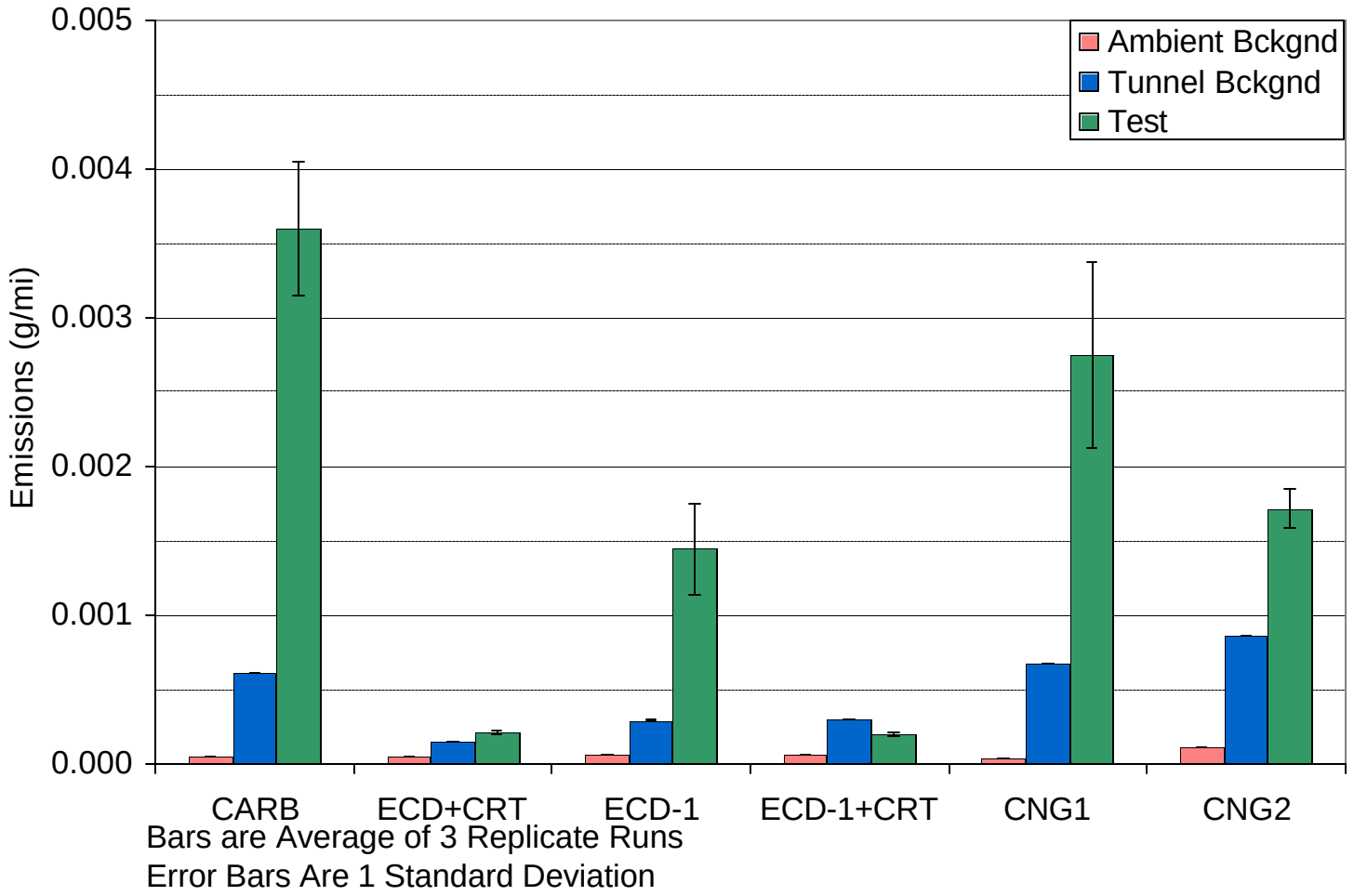
Volatile Organic Compounds

- nMHC clustering
  - 95 individual compounds identified
  - Hydrocarbon chains with C_2 – C_{11}
- Five compound classes defined
  - C_2 – C_5 Alkanes
  - C_2 – C_5 Olefins
  - C_{6+} Alkanes
  - C_{6+} Olefins
  - C_6 – C_{11} Aromatics

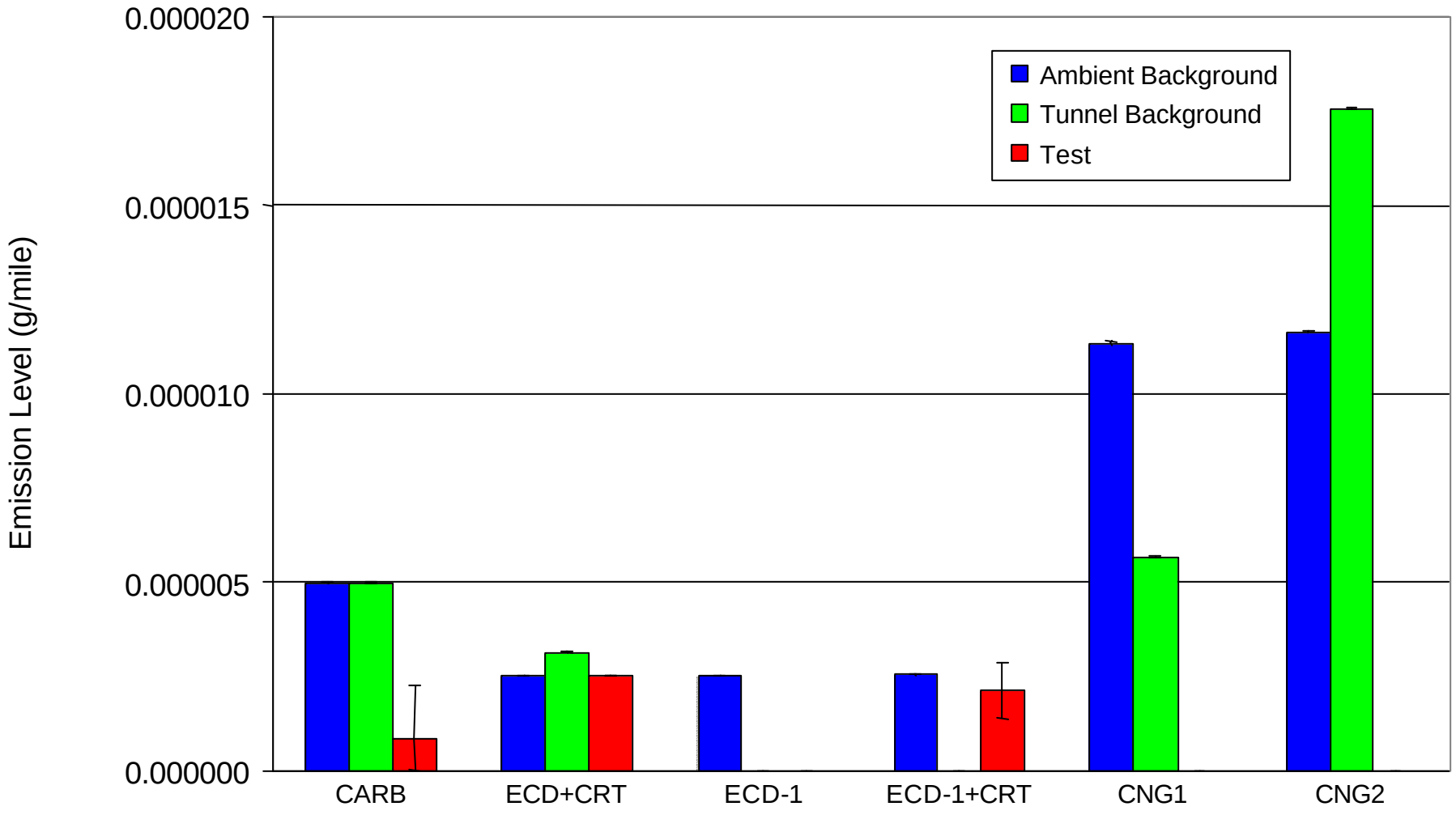
nMHCs by Compound Class



Speciation Data – Benzene



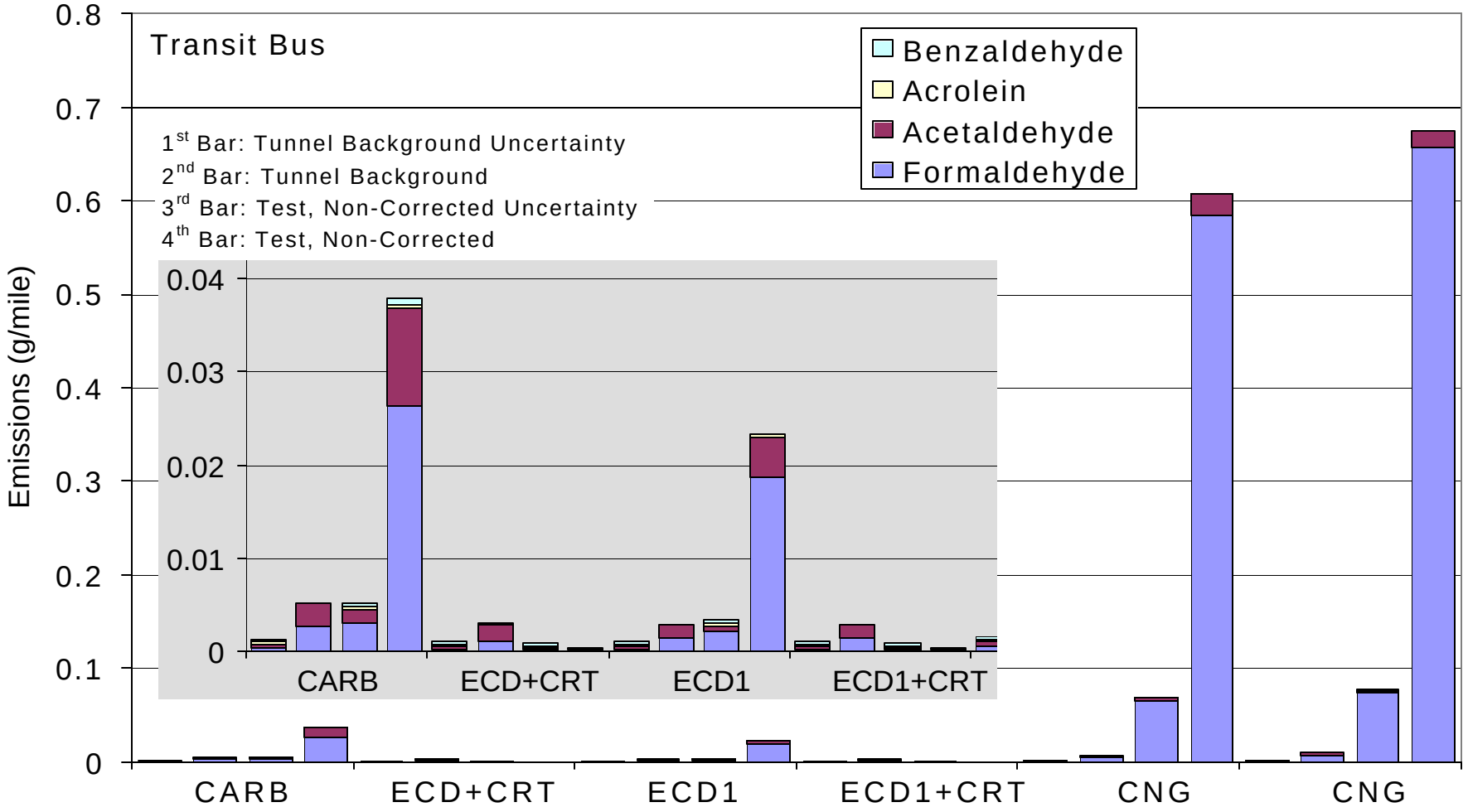
Speciation Data – 1,3 Butadiene



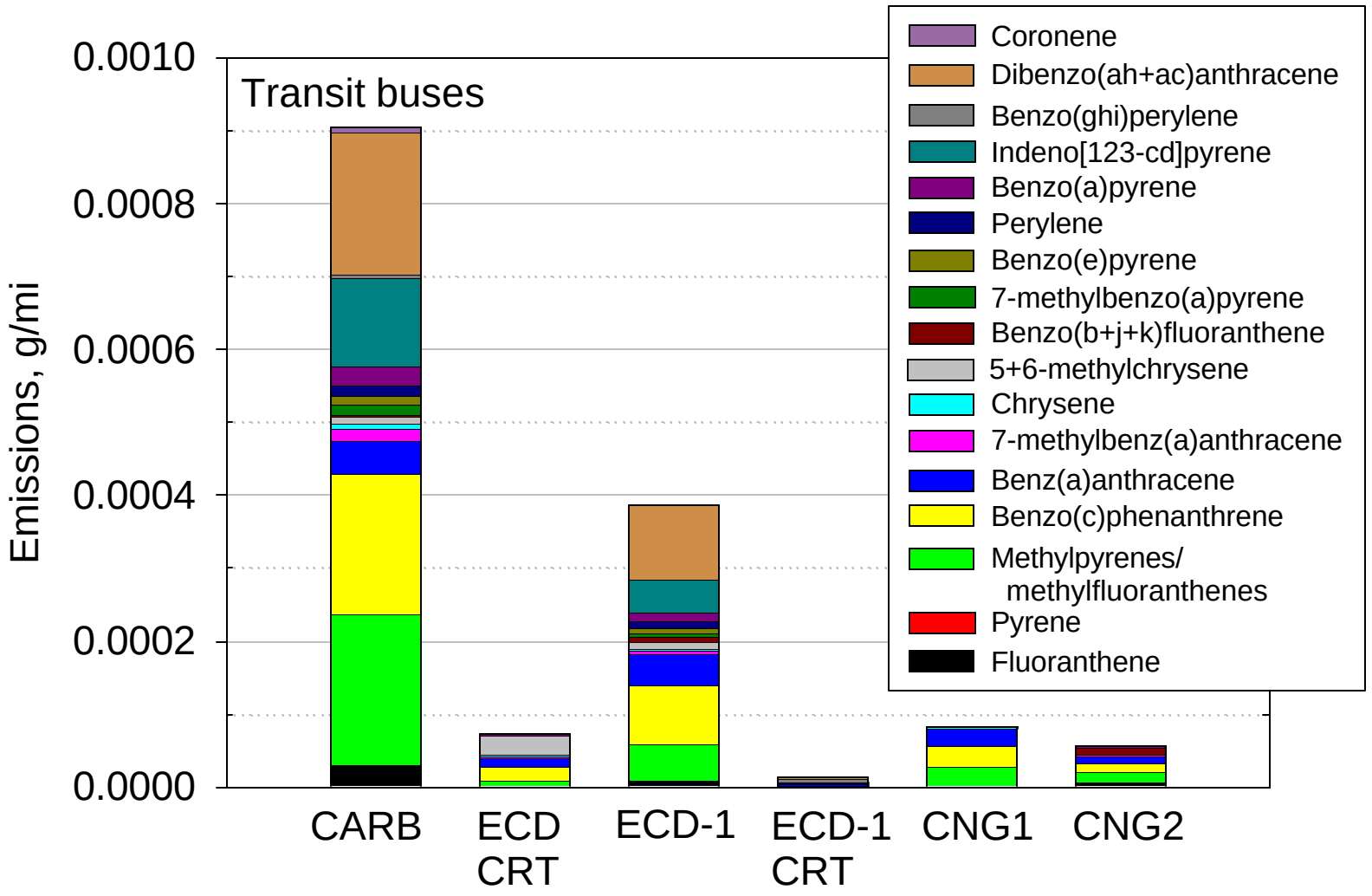
Speciation Data – 1,3 Butadiene

- Problems with detecting 1,3 Butadiene
  - Tunnel background levels varied between the morning and afternoon.
  - Difficult to separate from tunnel background levels.
  - Even though samples were analyzed within 2 hours of collection, possibility exists that there were still significant losses.
  - Samples in Tedlar bags can decay rapidly in the presence of diesel exhaust.
  - NO2 and HNO3 may reduce 1,3 Butadiene.

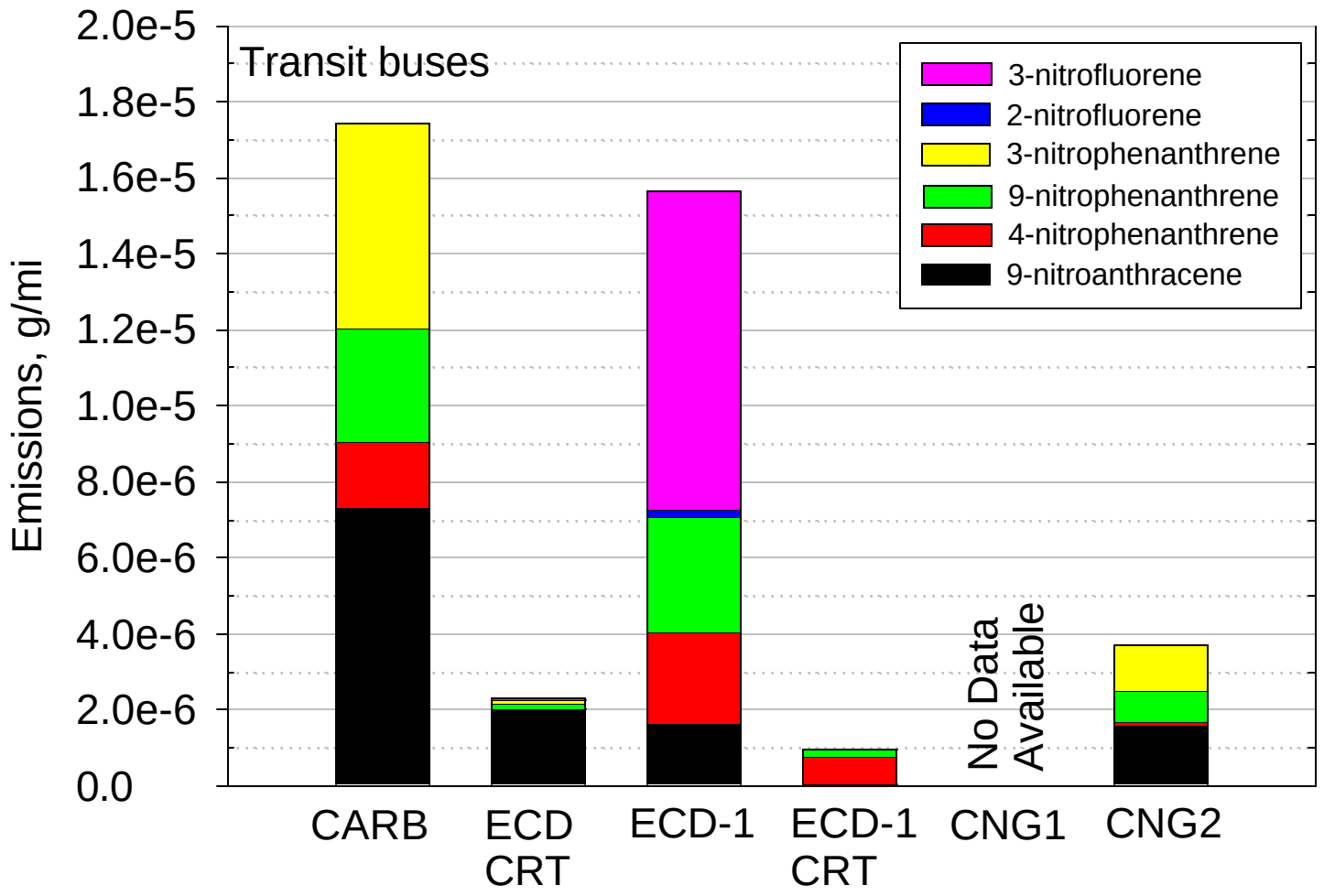
Speciation Data - Carbonyls



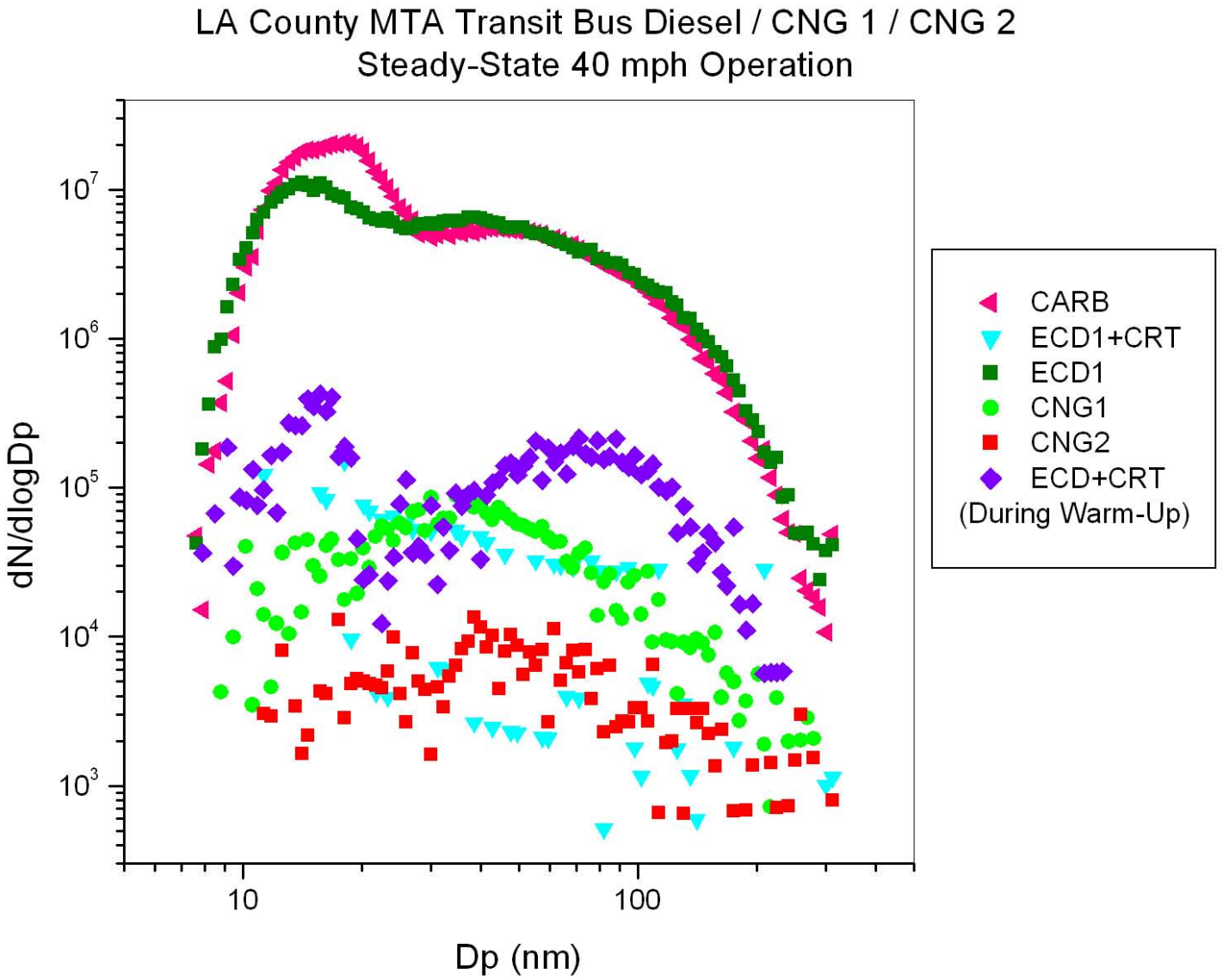
Speciation Data – 4+ Ring PAH



Speciation Data - 3 Ring Nitro PAH



Particle Size



Speciation Data Summary

Emission Components	ULSD w/DPF	CNG
PM		=
NOx		>
THC/NMHC		<<
CO		<<
Benzene		<
Aldehydes		<<
1-3 Butadiene		?
PAH		~
nPAH		~
Particle Size		~

Conclusions

- ULSD w/ DPF shows proven reductions of air toxics and ozone precursors.
- Proven Durability
- Power, performance and reliability not impacted by fuel or filters
- Total Emissions are comparable to CNG Heavy Duty Vehicles
- Preliminary Toxic Score
  - Diesel w/ DPF < CNG
  - Awaiting mutagenicity results & CNG with after treatment

Conclusions, continued

- Need to look at the total emissions:
  - Total toxics
  - Ozone Impacts – Area specific
- Published SAE Papers
  - 2002-01-0432 & 2002-01-0433
  - 2002-01-2873 will be available in Oct, 2002
- Websites:
  - www.ecdiesel.com
  - www.ctts.nrel.gov/heavy_vehicle/what/ec_diesel.html